HERBICIDES AS A PRE-TREATMENT FOR PASTURE RENOVATION

M. J. T. NORMAN, Grassland Research
Station, Hurley

Summary

1. An experiment at the Grassland Research Institute on permanent pasture, involving dates and methods of application of 2,4-D (amine) as a preparation for cultivating and sowing ryegrass and clover is described.

2. The immediate effect of herbicide treatments in general was to reduce markedly the cover of total herbs, to reduce that of total legumes, and to increase the cover of total grasses.

3. An account is given of the individual reactions to herbicide treatments of the nine major species present.

4. There has since been a decline in the proportion of herbs and an increase in legumes on all herbicide-treated plots.

5. Early establishment of both S.24 ryegrass and S.100 white clover was significantly higher on plots treated with herbicide than on control plots.

6. The proportion of ryegrass present in sown plots previously treated with herbicides has remained higher than that in untreated sown plots, but there is at present no difference between control and herbicide plots in respect of the proportion of S.100, which is uniformly low.

Introduction

An experiment was initiated on downland permanent pasture in autumn 1951 at the Grassland Research Institute, Hurley, to compare methods of renovation involving surface cultivations and broadcasting of a seeds mixture. In this experiment, the comparative lack of success in establishment of sown species was attributed partly to competition from the original herbage, which recovered rapidly from cultivation treatment. The original herbage contained a high proportion of dicotyledons, and it was hoped that by the use of herbicides before cultivating and sowing, competition from herbs would be reduced and an open sward more suitable for the establishment of sown species created. Accordingly, the experiment described below was laid down in spring 1953 and is still in progress.

Methods

The experiment is sited on a chalk escarpment of gradient approximately 1 in 8, facing north-northwest. The pasture, which is at least 12 years old, could be classified as Bent - Fescue - Cocksfoot with an abundance of herbs, and overlies a flinty loam grading into solid chalk at 7 to 9 inches depth. Average rainfall in the Hurley area is approximately 26 inches per annum.

The treatments involve a combination of both dates and methods of application of herbicides with subsequent cultivations and sowing. The herbicide used throughout was 2,4-D (amine) applied with a knapsack sprayer at 100 gallons per acre. The main treatments were:-

(a) First herbicide application May 1st (early application)
(b) First herbicide application May 15th (late application)

in factorial combination with:

(a) Cultivations and sowing of a seeds mixture in mid-July.
(b) No cultivations or sowing.

Each of these four combinations were split for the following treatments:

(a) No herbicide (control)
(b) 2 lbs per acre acid equivalent 2, 4-D (amine) in a single application. (single dose)
(c) 1 lb per acre acid equivalent of 2, 4-D (amine) followed 14 days later by a second application of 1 lb per acre (split dose)

Thus there are 12 treatments. Plots are 5 yds by 2 yds, and in subsequent grazing a complete block is grazed as one unit. 2 blocks were laid down in spring 1953 and two more on an adjacent site in spring 1954. In the subsequent paragraph dates quoted refer to 1953 for the first two blocks and to 1954 for the second two blocks.

All plots received 3 cwts per acre of Fison's No. 37 fertilizer (0-16-16) in early March and 2 cwts of Nitro-Chalk 14 days before the first herbicide application of early and late treatments respectively. After herbicide treatments all plots were cut for hay in late June. In mid-July the appropriate plots were cultivated four times with a heavy harrow, and broadcast with 10 lbs per acre S.24 perennial ryegrass and 2 lbs per acre S.100 white clover with no leaf mark, plus 1 cwt Nitro-Chalk per acre. Sheep were turned in immediately after sowing to graze down the original herbage and to tread in the seed. Grazing took place again in late August, which completed the management for the first year.

The 1953 blocks received 3 cwt of Fison's No. 37 and 2 cwts of Nitro-Chalk in early March 1954 and have since been grazed rotationally by sheep, beginning in mid-April.

Botanical composition was estimated in April, July and October by point analysis, using a fixed grid and at a sampling intensity of 100 points per plot. Estimates of hay crop yields were obtained by cutting with a motor scythe. Seedling density of ryegrass and white clover was measured by counts in random 6 in x 6 in quadrats.

Results

Hay Yield. Conditions for herbicide action under all treatments were good in May and June 1953, with moderate well-distributed rainfall and normal temperatures for the time of year. The corresponding period for 1954 was wetter, particularly in early June, and cooler throughout May, which may have affected adversely the kill obtained from early applications in 1954.

Hay cuts were taken three weeks after the final herbicide treatments, in the third week in June. Dry matter yields were depressed on treated plots by approximately one third that of controls (see Table 1). In this table and tables 2 and 4 the standard error shown in column (a) is appropriate for the comparison of herbicide treatment means at the same time of application, and that in column (b) for comparison of times of the same or different herbicide treatments.

For early applications, the effect of the split dose was to reduce yields more than the single dose, but this relation was reversed for late applications. The latter result would appear to be due to the short interval between the last herbicide application and the hay cut. Botanical separation of the cut herbage into grasses, legumes and herbs showed that the loss in yield under herbicide treatments was due to a direct reduction of legumes and herbs, the yield of grasses being largely unaffected.

Herbicide effects. The immediate effects of herbicide treatments upon the major species is shown in Table 2, in which results are expressed as the square root of cover as measured by the number of species-point contacts per plot. With the exception of Ranunculus bulbosus, the figures refer to point analysis carried out after the hay cut in July 1953 (first two blocks) and July 1954 (second two blocks). Ranunculus, being summer-dormant, could not be estimated in July, consequently figures for this species are taken from the analysis made in the following April and are thus only available for the first two blocks. Errors have not been given for Plantago lanceolata and Leontodon hispidus, since the high proportion of zero values made statistical analysis of doubtful validity, but the results for these species are so clear-cut as to render such analysis unnecessary.

The marked effect of all herbicide treatments upon the grass/legume/herb balance is immediately apparent from the table, total grasses being increased and total legumes and herbs decreased. The split dose was more effective than the single dose in bringing about these changes in all three components. However, only total herbs have been significantly affected by the time of application, late applications causing a greater reduction.

The herb species show clear differences in reaction to herbicide treatments. Plantago and Leontodon were most susceptible, all herbicide treatment having brought about a virtually complete kill. Herbicides in general have reduced Chrysanthemum significantly, late application being more effective than early, though there were no apparent differences in kill due to method of application. Ranunculus was also reduced by all herbicidal treatments, particularly when applied late, and for this species the split dose was more effective than the single. Veronica was the only important dicotyledon resistant to all herbicide treatments under trial. In fact, with the reduction in competition from other herbs, the cover of this species was significantly greater on treated plots than on the controls.

Of the major species other than herbs, Trifolium was reduced by herbicide applications in general, though there were no significant effects to be ascribed to time or method of application. Festuca and Agrostis increased considerably after herbicide treatment without any apparent differences due to time or method. Dactylis was alone among major species in showing no measurable reaction to treatment.

Many of the less important herbs occurred too sporadically for statistical analysis of their reactions; of these Prunella vulgaris, Bellis perennis, Euphrasia nemorosa, Potentilla reptans, Crepis capillaris and Leontodon autumnalis appeared to be moderately susceptible, while treatments had no discernible effects upon Viola hirta, Cirsium arvense and Knautia arvensis.

Apart from the herbicide treatments, it will be realised that the two controls differed in respect of the date of application of spring nitrogen, which was governed by the time of herbicide application to the two other plots of the main treatment. In no case was there any significant difference due to the effect of dates of nitrogen application alone on the species in control plots.

Subsequent Sward Development. At the time of the above botanical analyses, the swards which had received herbicide were open and in an unstable condition. The subsequent development of these plots and of the controls is given in Table 3, which shows the changes in percentage contribution to cover for the uncultivated plots of the first two blocks between July 1953 and July 1954. The salient points are the continued reduction in the proportion of herbs under the good grazing management of 1954, particularly in control plots, and a replacement of grasses by legumes (almost entirely Trifolium repens) in plots previously treated with herbicide. This replacement has been mainly at the expense of Agrostis and Festuca, but these grasses still contribute considerably more to the sward in herbicide-treated plots than in controls.

Seedling establishment. Three weeks after the hay cut, half the plots were cultivated with a heavy harrow and seed of S.24 ryegrass and S.100 white clover was sown. It is observed that plots which had received herbicide broke up more easily under the harrow than control plots, and thus provided a better seedbed for the sown species. Patches dominated by Festuca rubra however, proved very resistant to harrowing.

Table 4 shows the density of seedlings four weeks after sowing. During this four-week period in 1953, temperatures were about normal and rainfall adequate and well distributed, while in 1954, though temperatures were lower, rainfall was high. For both species establishment on herbicide-treated plots was significantly better than on control plots, though there were no detectable differences due to the time or method of herbicide application. Establishment in Festuca patches was noticeably poor.

The subsequent development of sown species and wild white clover is given in Table 5, which shows the percentage contribution to cover in the first two blocks in July 1954. The absence of leaf-mark on the S.100 strain has made it possible to distinguish it from indigenous white clover, but the ryegrass figures from sown plots include original and volunteer plants in addition to S.24. It can be seen that while sown plots previously treated with herbicide have maintained a higher proportion of ryegrass than sown controls (though the contrast is less striking than at the seedling stage), there is no real difference between treatments in the proportion of S.100, which is uniformly low. It is also apparent that while the effects of cultivations or herbicides alone upon wild white clover had disappeared by July 1954, the combination of these treatments has materially reduced the proportion of this species.

Discussion

There has been general agreement with the results of other workers in the reactions of individual species to herbicide. The sensitivity of Plantago lanceolata has been demonstrated in Holland (de Boer 1947), the U.S.A. (Marth and Mitchell 1944) and in England (Halliday and Templeman 1951), and the last-named authors also classify Leontodon hispidus as moderately susceptible to MCPA. In the present experiment both species have been shown to be highly susceptible to 2,4-D (amine).

Better control of Ranunculus bulbosus has been obtained than that reported by Willis (1950) or Holly, Woodford and Blackman (1953). Chrysanthemum leucanthemum has been shown to be moderately sensitive to June applications, a result in agreement with Waywell (1953) using 2,4-D (butyl)

(butyl) in Canada, though Marth and Mitchell (1944), de Boer (1947) and Halliday and Templeman (1951), applying various phenoxyacetic compounds, classify this species as resistant.

In this trial, Trifolium repens was moderately reduced by all herbicide treatments, but on the 1953 blocks has since recovered, contributing 14-16% to the total cover on uncultivated control and herbicide plots alike in July 1954 (Table 5). This reaction is in accord with results quoted by Ochiltree (1953) from leys containing S.100, and by Allen and Ochiltree (1953) for wild white clover in permanent pasture.

In this report, dealing as it does with an experiment still in progress, final conclusions cannot be drawn as to the ultimate value of herbicide treatments alone on this particular pasture, and a current assessment gives no real indication. A satisfactory kill of herbs and a gratifying recovery of white clover after its initial setback have been recorded; but the two main recolonising species have been Agrostis stolonifera and Festuca rubra, the former low-yielding and both unpalatable to sheep. Moreover, among the major herb species virtually eliminated, Plantago lanceolata is known to be mineral-efficient and highly palatable. Further, Dactylis glomerata, the most desirable of the original important grasses, has not increased on herbicide-treated plots more than on the controls.

With reference to the specific object of the experiment, i.e. to test the efficacy of herbicides as a pre-treatment for the establishment of sown species, the results to date have been moderately satisfactory. S.100 establishment has been poor in all cases, and has not yet compensated for the combined effect of herbicides and cultivation upon the original wild white clover. The highest proportion of ryegrass obtained by sowing after herbicide treatments has been 22.8%, but probably one-third of this figure represents unsown plants.

However, when the effects of management and manuring, herbicides and sowing are considered in relation to the previous botanical composition of the pasture, a marked improvement has taken place within twelve months with respect to the status of ryegrass and white clover. Taking the comparable figures for control plots in July 1953 as the yardstick, when ryegrass contributed 2.0% and white clover 6.7% to the sward, management and manuring alone has brought about an increase of 4.1% ryegrass and 9.5% white clover in a year; herbicides (all treatments) plus management and manuring 5.5% ryegrass and 8.3% white clover, and the combined effect of sowing with herbicides and management and manuring an increase of 16.6% ryegrass and 5.8% white clover.

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TABLE 1

Dry Matter Yield of Hay Cut (lbs. per acre)

Early Application			Late Application			S.E. ±	
Control	Single Dose	Split Dose	Control	Single Dose	Split Dose	a	b
2798	1865	1550	2584	1621	1878	131	150

TABLE 2

Immediate Herbicide Effect (square root of cover)

Species	Early Application			Late Application			S.E. ±	
	Control	Single Dose	Split Dose	Control	Single Dose	Split Dose	a	b
Total grasses	8.9	10.3	10.8	8.6	9.7	10.3	0.17	0.24
Total legumes	5.3	4.0	3.1	4.5	3.8	3.2	0.37	0.40
Total herbs	6.5	4.4	3.9	6.7	3.6	2.6	0.24	0.30
Agrostis stolonifera	3.1	4.6	4.4	3.2	4.2	4.2	0.31	0.30
Festuca rubra	5.2	6.2	6.5	5.0	5.9	6.3	0.30	0.30
Dactylis glomerata	4.1	4.2	4.2	4.2	4.2	4.6	0.27	0.34
Trifolium repens	4.4	3.5	2.8	3.8	3.2	3.0	0.33	0.42
Chrysanthemum leucanthemum	3.3	3.8	2.9	3.8	1.9	1.4	0.37	0.49
Plantago lanceolata	3.2	0.5	0.4	3.5	0.2	0.0		
Leontodon hispidus	2.8	0.5	0.1	2.7	0.0	0.0		
Veronica chamaedrys	1.6	2.6	2.4	2.0	3.1	2.8	0.37	0.38
Ranunculus bulbosus	4.4	3.4	2.8	4.6	3.6	1.6	0.33	0.31

TABLE 3

Botanical Changes between July 1953 and July 1954
(Percentage contribution to cover on unsown plots)

Sward Components	Early Application			Late Application		
	Control	Single Dose	Split Dose	Control	Single Dose	Split Dose
Total grasses	+8.1	-7.4	-9.4	+3.8	-1.4	-5.2
Total legumes	-1.8	+8.5	+10.9	+5.2	+3.9	+8.5
Total herbs	-6.3	-1.1	-1.5	-9.0	-5.3	-3.3

TABLE 4

Ryegrass and White Clover Establishment
(Square root of seedlings per sq. ft.)

Sown Species	Early Application			Late Application			S.E. ±	
	Control	Single Dose	Split Dose	Control	Single Dose	Split Dose	a	b
S.24 ryegrass	2.1	3.2	3.2	2.2	3.4	3.7	0.41	0.37
S.100 white clover	1.0	1.6	1.8	1.0	1.4	1.7	0.24	0.22

TABLE 5

Development of Ryegrass and White Clover
(Percentage contribution to cover)

		Early Application			Late Application		
		Control	Single Dose	Split Dose	Control	Single Dose	Split Dose
Sown plots	Ryegrass	10.2	17.9	15.6	14.1	17.9	22.8
	S.100 white clover	3.8	4.2	3.8	2.9	3.4	4.4
	Wild white clover	15.9	6.7	5.4	17.8	13.2	8.8
Unsown plots	Ryegrass	5.8	7.6	6.6	6.4	7.8	8.1
	S.100 white clover	-	-	-	-	-	-
	Wild white clover	16.2	15.6	14.0	16.1	16.2	14.3

"THE EFFECT OF 24-D (AMINE) ON JUNCUS ARTICULATUS"

T. H. DAVIES and R. P. DONEY, Ministry of Agriculture, N.A.A.S.

Summary

Plots in an even stand of Juncus articulatus in mid-Devon were sprayed with 1½ lb. 2,4-D (amine) active ingredient per acre in 1952. Cutting and slagging treatments were also applied alone, in conjunction with one another and with spraying. Assessments of green shoots were made one year and two years later. Up to 50% control was obtained on the sprayed plots. The cultural treatments did not affect the rush numbers to any great extent.

Introduction

The Jointed Rush (J. articulatus) is found throughout the South-West Province. Usually it is found growing in association with Common Rush (J. effusus) though frequently almost pure stands are found in mid and North Devon and Cornwall. Cases have occurred on Bodmin Moor where Jointed Rush has been present in grassland which has been ploughed for arable crops. The clumps of tough, matted roots (J. articulatus is known as Wire Rush in parts of Somerset) have then been a great nuisance to cultivations. Consequently it was felt that some pilot work should be done on the species. The site chosen was a wet, heavy permanent pasture known locally as a "moor". The 3 to 5 inches of clay loam soil was on a blue clay subsoil. The herbage carried was very poor in quality, the dominant grass being Agrostis. Only a very small amount of Wild White Clover was present and buttercups (Ranunculus spp.) were the main weed in addition to the rushes. Being very wet the field was utilized for summer grazing only. The rainfall of the area averaged 45-50 inches per annum and the field was at an elevation of 650 feet above sea level. The pH was shown by analysis to be 5.9, the phosphates were classified as low-medium and the potash medium-high. Previous manuring consisted of 2 tons per acre of Ground Limestone applied in both 1950 and 1951 and a dressing of 10 cwt. per acre of Basic Slag in May 1951.

Experimental Results

Layout - Seven treatments (including control) replicated three times in randomised blocks.

Plot Size - 10 yards x 20 yards approximately $^{1}/_{24th}$ acre.

Treatments -

1. 1½ lb. 24-D (amine) per acre + 8 cwt. Basic Slag per acre.
2. 1½ lb. 24-D (amine) per acre + cutting 4 weeks later.
3. 1½ lb. 24-D (amine) per acre + cutting 4 weeks later + 8 cwt. Basic Slag per acre.
4. Cutting three times (June to September).
5. Cutting three times + 8 cwt. Basic Slag per acre.
6. 8 cwt. Basic Slag per acre.
7. Control - No treatment.

Details of Spraying - The spray was put on at high volume (approximately 100 gallons per acre) with an adapted stirrup-pump type sprayer and graduated bucket.

Timing of Operations

The spray was applied to treatments 1, 2 and 3 on 16th June, 1952 in warm sunny weather. No rain fell for the next seven days.

The Basic Slag was applied to treatments 1, 3, 5 and 6 on 17th March, 1952.

The rushes on treatments 2 and 3 (i.e. cutting 4 weeks after spraying) were mown on the 14th-16th July, 1952.

The rushes on treatments 4 and 5 (cutting 3 times) were cut on 14th-16th July, 19th August and 22nd September, 1952.

On 30th April, 1953 the whole experimental area was mown over and the rushes removed to facilitate assessment.

Details of Assessments

Treatments	Average number of green shoots of *Juncus articulatus* per plot	
	7th July, 1953. 16 x 6 inch square quadrats per plot	23rd August, 1954. 20 x 12 inch square quadrats per plot
1. Spray + Slag	81	92
2. Spray + Cutting	60	100
3. Spray + Slag + Cutting	73	125
4. Cut three times	113	192
5. Cut three times + Slag	101	175
6. Slag only	143	151
7. Control	137	187

Discussion

All the plots that had received the 1½ lb. 24-D (amine) per acre showed about a 50% reduction in shoots of *Juncus articulatus* one year after the treatments were applied. Two years after spraying the plots appeared on casual examination to be showing a greater reduction. A second assessment however done in August 1954 showed that the percentage reduction had remained at approximately the same level.

Little difference was shown between the slagging, cutting and slagging plus cutting treatments when applied in addition to spraying though as no "spray only" treatment was applied it is difficult to assess what effect these cultural treatments did have on the sprayed plots.

Where the cultural treatments were applied alone good control was not obtained, the best being about 25% for cutting three times + slagging one year after spraying. It seems likely therefore that the cultural treatments did not greatly effect the spraying as discussed in the previous paragraph.

Observations made during many visits to the experiment during the last two years suggest that a more efficient utilization of the herbage is being obtained on the sprayed plots and also on those which have been slagged. In fact the improvement to the whole experimental area appears greater than the "counts" suggest.

Conclusions

The improvement of much of the land in Devon and Cornwall subject to J. articulatus depends on many things apart from mere killing of the rushes. Drainage schemes are usually essential, greater use of fertilizers and better control of stock necessary. However it is encouraging that a single spraying with 24-D (amine) in this experiment, where the drainage was bad, has shown a decrease of the rush by as much as 50% two years later.

Some problems in the ecology of rush infested pastures

A. D. Q. AGNEW.
Botany Department, U.C.N.W., Bangor.

Summary

The difficulties in analysis of rush infested pastures are discussed and an optical point quadrat method together with a type of line transect adopted. It has been found that there are two main types of *J. effusus* communities. Their differences are enumerated.

The clumping habit is discussed in relation to the species of plants growing inside and outside the clump. These two communities have been analysed for three different pastures and it is shown that certain species such as *Lotus uliginosus*, *Festuca rubra* and *Carex nigra* occur predominately within the clump whereas some, such as *Trifolium repens* and *Cynosurus cristatus*, are intolerant of this environment. The differences between communities within and outside the clump are discussed in relation to grazing pressure and competition with *J. effusus*.

It is shown that there is considerable variation in the concentration of buried seed of *J. effusus* in the soil of a rush infested pasture between contiguous soil cores. Figures have been obtained for the wind dispersal of seeds from *J. effusus* plants. It has been shown that the greatest concentration of seed falls on the leeward side of the plant and not directly beneath it. Very few seeds are blown more than 2.5 metres from a plant.

This study, the results of which are as yet very incomplete, has been carried out in North Wales during the past year while the author was investigating the problem of rush ecology with particular reference to the invasion of reseeded pastures under the auspices of the Agricultural Research Council.

The problem of elimination of rushes is outside the scope of the present paper, but in order to gain a knowledge of the factors affecting the establishment of a rush community, ecological analysis of such communities and certain work on seed dispersal and distribution have been carried out, the results of which are presented in this report.

In the districts studied the plants mainly responsible for rush infestation are *Juncus effusus* L. var. *compactus* Hoppe. and *J. acutiflorus* Hoffm. with a little *J. conglomeratus* L. *J. inflexus* L. is not involved to the same extent since soils overlying limestone are relatively uncommon in North Wales.

Due to the size and habit of growth of *J. effusus* ecological analysis of pastures containing it has presented some problems. The method of analysis finally adopted has been a point quadrat method as given in Levy (I) with an optical point taken instead of the more usual needles. The frame from which the points are taken is mounted on a stand 3ft. 6ins. high.

TABLE I

Percentage cover of species within and without rush clumps for three pastures.

	RESEEDED PASTURE (1949)		PERMANENT PASTURE (Lowland)		PERMANENT PASTURE (Upland)	
	Within clumps	Outside clumps	Within clumps	Outside clumps	Within clumps	Outside clumps
Agropyron repens	-	-	1	1.1		
Agrostis stolonifera	1.0	10.0	6	-	3.9	8.8
Agrostis tenuis	5.5	4.5	5	11.1	1.9	1.1
Anthoxanthum odoratum					1.0	5.5
Carex echinata					1.9	8.8
Carex flacca				1.1		
Carex nigra	5.5	1.8			16.3	9.9
Carex panicaea						3.3
Cerastium vulgatum				1.1		
Cirsium palustre			1	1.1	1.0	3.3
Cynosurus cristatus				5.56		
Deschampsia caespitosa					1.0	2.2
Deschampsia flexuosa						5.5
Epilobium palustre					1.0	-
Festuca rubra	3.7	-	6	4.4	3.9	-
Galium palustre	1.0	1.2				
Glyceria fluitans		3.6				
Holcus lanatus	12.1	24.5	4	21.5		8.8
Hylocomium squarrosum						3.3
Juncus acutiflorus	6.1	17.3	2	4.4	2.9	3.3
Juncus effusus	37.4	-	43.0		48.1	-
Juncus squarrosus						2.2
Lolium perenne	2.0	5.5				
Lotus uliginosus	15.7	1.2	8	1.1	3.9	3.3
Luzula multiflora				1.1	1.0	
Molinia caerulea					3.3	-
Phleum pratense	1.0	1.2				
Poa pratensis	1.0	1.8	1	1.1		
Polytrichum commune					1.0	12.1
Potentilla erecta					3.9	2.2
Prunella vulgaris				1.1		
Ranunculus acris			1		1.0	2.2
Ranunculus flammula		1.8				
Ranunculus repens	5.5	15.4	17	25.6		
Rumex acetosa		12	1	-		1.0
Sieglingia decumbens						3.3
Solidago virgaurea						1.1
Sphagnum subsecundum					1.0	2.2
Trifolium repens.	1.0	3.6		4.4		2.2

With any method however the clumped nature of the rushes makes it almost impossible to randomise the sites for the frame, thus a type of line transect has been developed. A line 100 ft. long is stretched at random over the area to be studied and the distance the line passes through rush clumps recorded. Ten transects have been found to be sufficient, and the mean length through which the transect cuts the clumps is expressed as a percentage of the whole. This method would seem to have possibilities for survey work on rush infested areas due to its speed and accuracy. In one test the cover of rush clumps as measured by the point quadrat method was 16.3% whereas by using transects it was found to be only 7.6%. Indeed in all cases where the clumps were clearly separated from one another in a pasture the cover was never found to be above 15%.

The point method therefore was used to analyse the pasture and these results corrected by the transects.

Two types of infestation by J. effusus have been observed, being that in which the rush clumps are each distinct and isolated from one another, and that in which the clumping is not immediately visible and there are no gaps between the rush plants.

In the former the rhizomes tend to form many branches each side of a long axis and so become arrow-shaped, whereas in the latter longer unbranched rhizomes are produced.

The development of these two types seems to be dependent on water table. Work is being continued on this but sufficient results have not yet been obtained to permit generalisations.

The two types were present in a pasture which was reseeded in 1949 and degenerated. The better pasture species, Festuca rubra, Lolium perenne, Phleum pratense, Poa pratensis and Trifolium repens were present in the 'open' clumped community. Of these only Festuca rubra and Phleum pratense were represented in the more dense community which had a poorer structure altogether containing Deschampsia caespitosa, Hydrocotyle vulgaris and Molinia caerulea amongst other species absent in the former. Juncus acutiflorus contributed 17.3% and 12.5% and J. effusus 4.5% and 26.5% of the total cover to the clumped and more dense communities respectively.

Due to the survival of the better pasture species in the clumped communities it was decided to sample the clumps separately to investigate the relative proportions of the species growing within the clump and those growing outside it. As before the optical point quadrat method was used.

It was found that there is a great difference both in the species present and their relative proportions. Table I shows the percentage cover of the species inside and outside the clumps for three different pastures.

These pastures were chosen for their variety, so that it would be possible to show whether any differences were constant under different conditions.

Time has not been available to subject these figures to statistical treatment so that only the broadest conclusions can be drawn from them.

The habitat within a rush clump will modify the community within it due to two main causes namely competition with the rush and the relaxation of grazing pressure. In general those species which are heavily grazed outside the clump and absent within it, such as Cynosurus cristatus and Trifolium repens, are those which cannot compete with the rush. Those which are palatable but present in a greater proportion inside the clump, such as Lotus uliginosus and Festuca rubra can compete with J. effusus and benefit from the relaxation of grazing pressure.

Certain species which are extremely palatable, such as Lolium perenne and Phleum pratense, cannot compete with the rush to the same extent but can exist within the clump. In the reseeded pasture shown in Table I no fruiting heads of either of these two species were seen outside the clumps. This was due to the selective grazing outside the clumps. This suggests that in rush infested land which is liable to heavy poaching by cattle, being waterlogged for a large part of the year, seed from palatable species will slow down the rate of reversion. Where rush clumps provide the only potential source of seed they could have a beneficial effect on the pasture.

The studies so far dealt with have been the analysis of rush communities. Another aspect of the ecology of these communities is the dispersal and distribution of seed from J. effusus.

It has been suggested that one cause of invasion of J. effusus after reseeding is buried seeds in the soil. With this in view populations of buried seeds have been analysed from undisturbed rushy pastures.

Soil cores were taken 2 ins. in diameter and divided into one inch samples down to a depth of seven inches. These seven samples were spread out in pans to germinate in a warm greenhouse and seedlings were counted as they appeared. After six weeks there was no further germination, although each sample was then dried and stored to be put out again in conditions suitable for germination some weeks later.

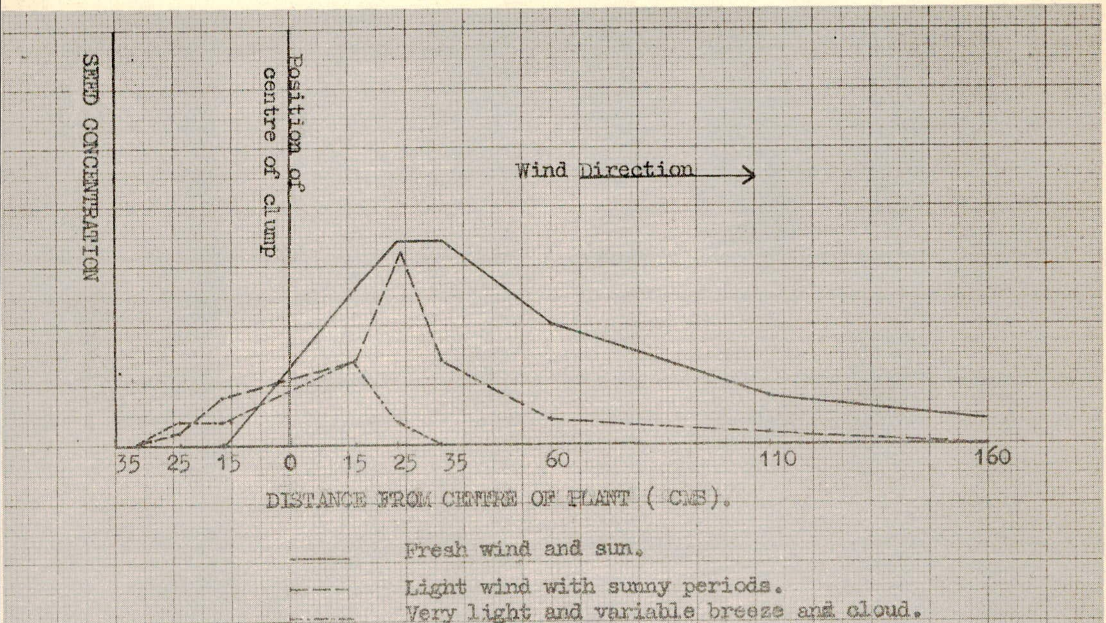
In one set of contiguous cores the number of buried seeds for each depth is shown in Table II. It can be seen that the variation between samples at the same level is great and that no conclusions can be drawn about the concentration of seeds in various levels in the soil or at various positions on, say, a surface transect. This was found with all the sets of cores so far analysed.

TABLE II

Numbers of viable seeds found at various depths in contiguous soil cores.

Depth in inches	1	2	3	4	5	6	7
Core No.							
1	68	36	47	38	61	38	25
2	43	55	40	61	45	53	76
3	78	55	57	59	56	78	52

Seed dispersal has been measured from individual plants of J. effusus. Blown seeds were collected on vaselined plates of equal size placed at various distances from the centre of a clump of J. effusus. The graphs given show the relative concentrations of blown seed caught against distance from the centre of the plant, in the direction of the prevailing wind at the time of collection. A typical scatter of seed is given for three different wind conditions.



SEED DISPERSAL FOR THREE DIFFERENT TYPES OF CONDITIONS

It has been found that no seed is liberated during wet weather and that once a capsule has dehisced and been wetted, very few seeds are liberated by the wind due to the wetting of the mucilaginous coat of the seed. This, when dry, adheres the seeds to the capsule wall. In this case either the capsules fall or are blown off individually or the entire inflorescence falls to the ground after the rotting of the stem. In either case large concentrations of seed will be deposited in a small area.

Blown seed also tends to be concentrated in one place as the graph shows, not around the base of the plant but on the leeward side of it from the prevailind wind and some distance from it.

These phenomena might account for the variable concentration of seeds in the soil.

Trials have been laid down to determine the rate and method of burial, and until these are analysed it will not be possible to verify this conclusion. In any case it seems likely from the graph that only a negligible proportion of the seeds will be blown more than 2.5 metres from a plant, and thus invasion of a reseeded pasture must occur through buried seed and not from seed blown from other areas.

No experiments on the possible dispersal of seed by water have yet been carried out. This aspect will be investigated.

It is emphasised that the results discussed in this report are in no way final. Research is continuing on all the above points.

References

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AN EXPERIMENT ON THE CONTROL OF CREEPING THISTLE (CIRSIUM ARVENSE) IN PASTURE

S. J. WILLIS, Shuttleworth Agricultural College,
Old Warden Park, Nr. Biggleswade, Beds.*

Summary

The experiment suggests that herbicides based on various formulations of M.C.P.A. and 2,4-D can give a considerable control of creeping thistle shoots for a period of at least two years after treatment. There is an indication that the effectiveness of the herbicides decreases at rates exceeding 1 lb. acid-equivalent per acre.

Introduction

This report is concerned with the results of a single experiment; any conclusions drawn, therefore, must be of limited value and need further verification. The value of the work has been reduced, to some extent, by the fact that in laying down the experiment an error was made in measuring out the sodium salt of 2,4-D, so that all the rates applied for this preparation were higher than was intended. However, the results for the remaining materials are not without interest and are suggestive of at least one problem that needs to be further elucidated; for this reason the results are being put before the present conference.

The experiment set out to test the effectiveness of three different formulations (sodium salt, amine, butyl ester) of M.C.P.A. and 2,4-D, each applied at three different rates (½, 1, 2 lbs. per acre), against creeping thistle (Cirsium arvense) present in old permanent pasture. The addition of two controls made a twenty plot lay out and this was replicated three times in the form of a randomised block making sixty blocks in all. Each plot was 1/200th. acre in area. The weedkillers were applied, using a pneumatic-type knapsack sprayer, on June 29th and 30th, 1950 in still weather conditions. The spray application was made at the rate of 100 gallons per acre. At the time of spraying most of the thistles were in the flower bud stage although there was a wide variation in the maturity of the plants. By July 7th the thistles on all treated plots were showing twisting, by July 25th the upper leaves of treated shoots were turning yellow while the lower leaves were already brown and by August 8th, apart from an odd survivor or two, all the thistle shoots were dead. It was obvious there had been a slight amount of spray drift on to the control plots but the bulk of the thistle shoots on these plots appeared to be unharmed.

Experimental results

Prior to spraying the numbers of thistles on each plot had been assessed by counting the shoots in ten random throws of an 18" square frame. The intention was to make further counts at the flower bud stage for three consecutive years beginning the year after spraying, (i.e. 1951). In fact,

*Work undertaken while at the Hertfordshire Institute of Agriculture, Oaklands, St. Albans.

counts were only made in 1951 and 1952. As the area has now been reseeded no further counts will be possible. The summarised results for 1951 and 1952 are given in the Table, expressed as percentage reductions of the pre-spraying counts.

Growth Regulator	Formulation	Rate lbs./acre	%age Reduction 1951	Av. of 3 plots 1952
M.C.P.A.	Sodium salt	½	99	78
		1	81	61
		2	88	73
	Amine salt	½	89	72
		1	92	83
		2	83	60
	Butyl ester	½	90	76
		1	96	84
		2	90	63
2,4-D	Amine salt	½	89	74
		1	80	58
		2	46	71
	Butyl ester	½	78	67
		1	93	80
		2	71	74
Control (Av. of 6 plots)			43	39
Significant Diff. (approx.x) (5% point)			31	23

xAnalysis carried out on transformed figures.

Conclusions

The only statistically significant conclusion to be drawn from these results is that at most rates, all the herbicides used were capable of giving a considerable kill of thistle shoots for a period of at least two years after treatment. Although the control appeared to be 100% in the year of treatment there was some recovery by the first year after application and this continued into the second year after application. The exact measure of control achieved by the first and second year after application is difficult to assess owing to the high percentage reduction on the control plots, but on the average it is <u>at least</u> 40% for the first year and 30% for the second. The high percentage reduction in the control plots is difficult to explain; observations made soon after spraying make it unlikely that drift was entirely to blame.

Although statistically insignificant, the results indicate that M.C.P.A. may have been slightly more effective than 2,4-D and the ester formulation somewhat more effective than the other two.

The differences between rates of application are deserving of greater attention as these approach very near to statistical significance. There is a definite suggestion in three cases of a falling off in the effectiveness of the herbicide with increase in rate of application beyond a certain point. The position of this point seems to be about the 1 lb. per acre rate. In no case, excluding the results for the sodium salt of 2,4-D, over the two years was a 2 lb. per acre rate recorded as giving the highest reduction. This matter invites further investigation.

On the experimental area there were also a number of spear thistles (Cirsium vulgare). Observations suggested that these were also controlled by the treatments.

Comment on the method of assessment

When the site for the experiment was chosen it appeared to have a dense, evenly distributed infestation of thistles. On making the first counts, however, it became obvious that the thistles tended to be in small clumps (presumably clones) so that it was possible for a plot to be placed in such a way as to contain only a small number of thistles. In view of the uneven distribution it is felt that the method of assessment was not altogether satisfactory. Unfortunately, as the results were being treated in the form of percentage reductions, the degree of accuracy could never be improved subsequently beyond the accuracy of the pre-spraying counts which were based on ten random quadrats. Of the 120 percentage reduction figures obtained over the two years 1951 and 1952, eight were definitely out of line with the remainder and it is interesting that half of these were from plots with very low thistle counts.

In 1952 the thistle counts were made using twenty throws of the 18" quadrat and these have been analysed separately using shoot numbers (i.e. comparing the numbers of shoots on the treated plots with those on the control plots) as well as by the percentage reduction method. Despite the weaknesses of the shoot numbers method in a case such as this, it is interesting to note that the main conclusions are the same as before. Again it was true that in no case did the 2 lb. per acre rate give the best control.

Dr. K. Holly: Our results agree with Mr. Willis' in that we did find a fall off in the control of the thistle when a certain dose was reached. This dose in one experiment was as high as 3½ lbs. MCPA per acre. I would like to ask Mr. Willis how much competition there was in his pastures in subsequent years? In the second year after spraying in his experiment reductions were still high, but we have found that in some poor pastures thistles appear remarkably quickly in the second year after spraying ceases, even when treated in three consecutive years.

Mr. S. J. Willis: The particular area where my experiment was carried out was old parkland. My impression was that it was not a very competitive sward for the thistles. On the other hand it might have been that the thistles were not very strong either. We did observe, you will recall, that the thistle population decreased even on the control plots.

Mr. S. G. Jary: I think in any investigation of the effectiveness of herbicides on creeping thistle it is very important to bear in mind the volume of water in which the herbicide is applied. Has Mr. Willis any information on this?

Mr. S. J. Willis: All my work was done at what we now usually call high volume (100 gallons per acre). I am afraid I cannot comment on whether results are likely to have been different if a lower volume had been used as such treatments were not included. However, I certainly agree with Mr. Jary that that point does need to be kept in mind.

Dr. E. W. Debney: Mr. Willis mentioned that the creeping thistle plants were smaller in the control plots than in the rest of the field. In the paper that has been circulated he states that there was some yellowing, probably due to spray drift. I would like to know what precautions Mr. Willis took to make sure there were no rhizome connections between sprayed and control plots.

Mr. S. J. Willis: The answer is very simple. I took no special precautions. I should, however, say that I made no estimate of the size of the shoots. I was referring to numbers of shoots when I stated that they were reduced on the control plots. It may well be that reduction was caused through a rhizomatus connection. The chief argument against this theory is that many of the control plots were surrounded on all sides by treated plots and there seemed to be no correlation between the severity of the application to the adjacent plots and the stunting on the control plots. If the theory I advanced was correct then presumably the thistles in the control plots, in the areas of the heavier rates of application, should not have had so much herbicide translocated to the rhizomes.

Mr. J. Elliott: The observations we made in the North of England this year (on rushes) suggest that in a re-seeded pasture infestation of rushes can occur, in the year of seeding and in the following year.

Could Mr. Agnew comment on the fact that he found no further germination after six days in his pot experiments?

Mr. A. D. Q. Agnew: The soil samples we used were sieved to reduce their volume and then placed on damp sand in a greenhouse. The conditions were extremely favourable for germination and approximately 100 per cent. of the seeds grew. This would not happen in a pasture; for one thing in the wet pasture there might be heavy poaching. Rush seed concentrations, as you probably know, are very high in rush infested pasture or pastures which have been rush infested, and any poaching will bring more seeds to the surface. New seedlings may be the result of delayed germination as well as new seeds brought to the surface.

Mr. O. G. Williams: I would like to raise two points on Mr. Agnew's paper. The first is in connection with the species analysis of the sward. Does he think that stock do in fact graze the grasses growing within the clumps of rushes? If not, should they be recorded as useful grazing?

The second point concerns Mr. Agnew's statement that cattle, when they puddle rush infested land during the winter months, create conditions for the better species to germinate. I think our experience is that where the surface is broken the rushes tend to germinate, and not the useful species.

Mr. A. D. Q. Agnew: I quite agree that rushes are the usual species which colonise. I was speaking specifically of the lack of grazing within the clump. One species, *Lotus uliginosus* grows very well outside the clump where it is allowed, but under the pasture conditions, I have been investigating the *Lotus* is grazed either completely away or absolutely flush with the sward surface outside the clump, and left to flower and fruit within the clump. I made the point about a possible germination of better pasture species in puddled areas merely because it occurred to me that the only place that the better pasture species could flower and fruit was within the clumps and that would probably be the only source of seed after reseeding, but very probably the only thing that happens in poached areas is that *Agrostis spp.* will either come in or rushes will invade. I think it would probably be *Agrostis* before the rushes.

Mr. Campbell: I wonder if in Mr. Agnew's opinion the dispersal of rush seeds by wind is of much practical significance as compared with such dispersal agencies as animals and surface water? Rush seeds can be carried considerable distances in the wool of sheep, in the soil adhering to the feet of animals, and in surface water following heavy rain.

Mr. Agnew: Certainly rushes sometime distribute themselves along paths and on the uphill sides of dykes, particularly in hill land. I don't know whether this is due to the puddling of the soil on the path creating good conditions for seed germination or not. I am doing experiments at the moment on the effect of surface water on seed dispersal down slopes. The seeds are mucilaginous, they could stick to things, but I haven't looked at sheep's wool.

Anonymous: Two brood mares dropped their foals after grazing on pasture that had been treated with 'hormone' weedkiller. Is it likely that there was any connection between the two events?

Dr. E. Holmes: I know that allegations have been made that abortion has been caused by the application of MCPA to grassland but in none of the cases that we as a Company have investigated has there been any real evidence that the herbicide was responsible. The history of the herds has suggested the contrary.